



AMENDMENT OF SPECIFICATION

On Page 2, amend Paragraph 0007 as follows:

[0007] The distribution system 17 is also a single-fault-tolerant system and as such is capable of withstanding a single line or power distribution path malfunction. In using the system 10, when one power source or converter is not operating appropriately, for example, when a malfunctioning ~~and thus~~ line 24 is not operating appropriately, the remaining two power sources and corresponding converters or lines 26 may remain operating and provide proper power to the controller 16.

On Pages 2-3, amend Paragraph 0008 as follows:

[0008] When line 24 malfunctions a best response can be determined from the remaining two lines 26. Unfortunately, when a second line is also malfunctioning, such as the one designated as line 28, a majority determination cannot be easily performed, since one may not be able to determine which of the remaining two lines 26 is correct and which is malfunctioning. The redundant system 10 is sometimes referred to as a R(2/3) system, defined as one where two out of three elements are required to provide appropriate outputs at terminal 20.

On Pages 3-4, amend Paragraph 0012 as follows:

[0012]. Referring now also to Figure 2, a traditional DC/DC converter 29, which is representative of the power converters 18 in Figure 1, is shown. The converter 29 includes a main controller 30 that is coupled to multiple transformers T1, T2, and T3 for voltage conversion, isolation of input voltage at input terminal 31 from output voltage at output terminal 32, and isolation of multiple regulated feedback loops 33. An auxiliary regulator circuit 34 provides power to the controller 30. The converter 29 includes input filters 35, an inrush limiter 36, and other common circuitry known in

the art. In operation the controller 30 monitors a reference voltage and the converter output voltage and current through the feedback loops 33 and adjusts voltage output of the converter 29 by adjusting energy flow across the third transformer T3. The controller 30 may activate or deactivate the converter 29 on command, allowing the system 10 to switch between power sources 12, processing units 14, and converters 18 or lines 22.

On Page 4, amend Paragraph 0014 as follows:

[0014] Referring now to Figure 3, another example of a majority redundant power distribution system 38 utilizing "ORing" diodes 39 is shown. Two power sources 40 are utilized rather than three, as with the previous example, and are coupled to three processing units 41 of a controller 42. Diodes 39 are coupled between outputs 43 of a pair of power DC/DC converters 44 and input 45 of a ~~center processing unit~~ center one 46 of the processing units 41. Diodes 39 are referred to as "ORing" diodes because they operate in a logical OR manner to provide power from either ~~power converter~~ the one designated 48 or ~~power converter~~ the other designated 50 of the power converters 44 to the center-processing unit 46. Thus, for example, when either power converter 48 or 50 is malfunctioning, the other or properly operating power converter supplies power to the center-processing unit 46 through diodes 39.

On Page 9, amend Paragraph 0043 as follows:

[0043] Referring now to Figure 4, a block diagrammatic view of a power distribution network 60 in accordance with an embodiment of the present invention is shown. The network 60 includes power generators 62 69, 71 that generate power to supply multiple unregulated loads 64 70 and regulated loads 72. Distributors ~~66~~ 61, 63, 67 are coupled to the generators ~~62~~ 69, 71 and distribute power from the generators 62 to multiple regulated or redundant power distribution systems 68 and unregulated loads 70. The unregulated loads 70, for example, may include lights, fans, motors, heaters, blowers, or other unregulated loads known in the art. On the other hand,

regulated loads 72, which are coupled to the redundant systems 68, may include devices such as computers, sensors, navigation systems, or other regulated loads known in the art. In general, the regulated loads 72 are more sensitive to voltage line swing or variations and have their received power signal-conditioned before being utilized therein. Without the received power being signal-conditioned the regulated loads 72 may operate inappropriately, degrade over time, or become inoperable. The regulator circuits 68 are described in detail below.

On Pages 9-10, amend Paragraph 0044 as follows:

[0044] A normally closed switch 59 is coupled to a first distributor 61 and a second distributor 63. A normally open switch 65 is coupled to the second distributor 63 and to a third distributor 67. States of the switches 59 and 65 change when either of the power generators 62 69, 71 are operating inappropriately. For example, when the first power generator 69 is operating inappropriately, the normally closed switch 59 opens and the normally open switch 65 closes, such that the second power generator 71 is supplying power to the second distributor 63 and the third distributor 67.

On Page 10, amend Paragraph 0047 as follows:

[0047] An R(1/3) regulator 84 is coupled to the lines 76 and supplies power having a highly reliable and regulated voltage level corresponding to a proper voltage level of the lines 76 to a serial interface module 97. The module 97 contains a bus interface 85 where it is ~~than~~ then used to transmit the majority signal 83 to a system data bus 86. See R(1/2) dual-redundant regulator circuit of Figure 12 for further detailed explanation of a sample R(1/3) triple-redundant regulator circuit that may be used for the R(1/3) circuit 84, where only one of three regulator circuits is then needed for operation of module 97.

On Page 11, amend Paragraph 0050 as follows:

[0050] Referring now to Figure 6, a block diagrammatic and schematic view of a dual redundant power distribution system 87 incorporating use of distribution switches ~~88~~ 92, 93 in accordance with an embodiment of the present invention is shown. The dual redundant system 87 includes a pair of power sources 89 that are coupled to regulated loads (not shown) via output terminals 90. The sources 89 have a pair of power bus terminals 91. A first input distribution switch 92 and a second input distribution switch 93 are each coupled to each bus terminal 91. A pair of power converters 94 are respectively coupled to the switches 92 and 93. A first output distribution switch 95 and a second output distribution switch 96 are each coupled to each of the converters 94. The output terminals 90 ultimately receive power from the output switches 95 and 96. Distribution switches ~~88~~ may be added upstream or downstream with respect to the converters 94.

On Pages 11-12, amend Paragraph 0051 as follows:

[0051] An example of a distribution switch ~~88~~ as mentioned with respect to Figure 6 is shown in Figure 7. The distribution switch 88 includes a pair of power distribution modules 102. Each module 102 includes a first power transistor 104 in series with a second power transistor 106. The first transistor 104 and the second transistor 106 have source terminals 108, drain terminals 110, and gate terminals 112, respectively. Source terminals 108 are separately coupled to associated power sources 114, which may represent power received from any device including sources 89 and converters 94 as described for Figure 6. The drain terminals 110 are coupled to each other and are also coupled to a sensor 116. The gate terminals 112 are coupled to each other and to controllers 118, which may be separate from the switch 88 and part of a single controller. The controller 118 may also be microprocessor based and formed of various

logic devices.

On Page 12, amend Paragraph 0053 as follows:

[0053] Referring again to Figure 6, there is minimal voltage drop across the distribution switches ~~88~~ 92, 93. Also, the distribution switches ~~88~~ 92, 93 are capable of withstanding single point failure (SPF). SPF describes inoperability of a system due to one point of failure of any kind within a particular circuit of concern.

On Pages 12-13, amend Paragraph 0054 as follows:

[0054] The power converters 94 in Figure 6 may include a primary regulator 122 (only one is shown) in series with an isolation transformer 124 (only one is shown), which is again in series with a secondary regulator 125. The regulators 122 maintain a proper input voltage for the load terminals 90 and provide DC/DC conversion. For example, a source may supply 28V DC, which may then be converted to and regulated near 5V DC by the regulator 122. The transformers 124 provide isolation between the load terminals 90 and the sources 89. Isolation between terminals 90 and sources 89 is desired to eliminate ground-loop current flow through the power system 87. The regulator 122 and the transformer 124 and the regulator 125 are shown in further detail in Figure 13.

On Page 130, amend Paragraph 0055 as follows:

[0055] Referring now to Figure 8, a block diagrammatic and schematic view of ~~the~~ a simplified dual redundant power distribution system 87' ~~of Figure 6 simplified~~ and in accordance with another embodiment of the present invention is shown. The dual redundant system 87, of Figure 6, may be simplified when weight and costs are deemed to have a higher priority than difference in reliability between the dual redundant system 87 and the simplified dual redundant system 87', which in one embodiment is

approximately equal to 0.000266 wherein the dual redundant system 87 has a reliability level of 0.998890 and the simplified dual redundant system 87' has a reliability level of 0.998624. Reliability values are determined using Bayes Theory for Reliability Estimation. As such, the input distribution switches 92 and 93 are eliminated and the power sources 89 are directly coupled to the converters 94. In so doing, the number of components within the dual redundant system 87 is reduced to form the simplified dual redundant system 87', thereby reducing weight and costs. Reliability may be determined using mean time to failure quantities for each device within a system or circuit under evaluation as is known in the art.

On Pages 13-14, amend Paragraph 0056 as follows:

[0056] Referring now to Figure 9, a block diagrammatic and schematic view of a triple redundant power distribution system 130 incorporating two input distribution switches 132 and three output distribution switches 134a, 134b, 134c in accordance with another embodiment of the present invention is shown. The dual redundant system 87 in Figure 6 for two independent loads (not shown) again is modified to form the triple redundant system 130 for three independent loads (not shown) by introducing an additional output distribution switch 134c, which is also coupled to each of the converters 94. Reliability of the triple redundant system 130 is approximately equal to 0.998891. Although, any number of distribution switches may be used, introduction of additional switches beyond that as shown in Figure 9 may or may not provide any added benefit, since with an increased number of components comes an increased potential of any one component malfunctioning at any given instance in time. Thus, for each additional switch the amount of increase in system overall reliability diminishes.

On Page 14, amend Paragraph 0057 as follows:

[0057] Referring now to Figure 10, a block diagrammatic and schematic view of a triple redundant power distribution system 140 incorporating distribution switches 142 and having an additional power bus terminal 144 in accordance with another embodiment of the present invention is shown. The embodiment of Figure 10 is shown to illustrate another example of a triple redundant system with use of only a single output distribution switch, such as switch 146, and to also illustrate that an additional power bus terminal or power source, such as terminal 144, may be formed through use of a single input distribution switch 148 coupled to each source 89.

On Pages 14-15, amend Paragraph 0058 as follows:

[0058] Referring now to Figure 11, a block diagrammatic and schematic view of a dual redundant power distribution system 150 incorporating use of a redundant regulator circuit 152 in accordance with another embodiment of the present invention is shown. The dual redundant system 150 includes a pair of primary regulators 164, 170 coupled to a pair of isolation transformers 166, 172 which are coupled to the regulator circuit 152. The regulator circuit 152 includes a first secondary regulator 158 and a second secondary regulator 160 that are coupled to the isolation transformers 166, 172, respectively. The regulators 158 and 160 have a common output terminal 162. A first primary regulator 164, a first transformer 166, and the first secondary regulator 158 form a first power distribution line 168. A second primary regulator 170, a second transformer 172, and the second secondary regulator 160 form a second power distribution line or possible power distribution path 174. The regulators 158 and 160 may be linear regulators having low dropout voltage, no reverse current, and with thermal and over-current protection, such as for example regulators of the type LT1764 from Linear Technology Corporation. The regulator circuit 152 is illustrated in greater detail in Figure 12 and the distribution line 168 is illustrated in greater

detail in Figure 13.

On Pages 16-17, amend Paragraph 0062 as follows:

[0062] Referring now to Figure 13, a block diagrammatic and schematic view of the distribution line 168 is shown. The distribution line 174 is similar to that of 168. The primary regulator 164 includes a main current supply line 210 that supply power to the first secondary regulator 158 and is controlled via a main controller 212. The controller 212 monitors voltage across a house-keeping power source circuit 236 and compares that voltage with a reference voltage from a reference source 216 to adjust amount of current passing across the first isolation transformer 166 and thus adjusting voltage across the resistor 214 to be approximately equal to the reference voltage and thereby regulating voltage received by the regulator 158. The controller 212 operates in current-mode control by monitoring voltage across a current feedback resistor 214. The controller 212 generates an error signal in response to difference between voltage of the housekeeping circuit 236 and voltage of the reference 216. The error signal is intercepted by a voltage signal across the resistor 214 where current flows therethrough. This intercepted voltage signal is a pulse width modulated signal to activate and deactivate a power switch 218. Pulse width of the modulated signal is increased or decreased to increase or decrease energy across the transformer coil 227. The controller 212 may also be microprocessor based or formed of various mixed-signal devices.

On Page 18, amend Paragraph 0067 as follows:

[0067] Referring now to Figure 14, a block diagrammatic and schematic view of a dual redundant power distribution system 150' incorporating use of a pair of redundant regulator circuits 260 with primary regulator circuits 122 and isolation transformers 124 in accordance with another embodiment of the present invention is shown. Instead of a single

regulator circuit being coupled to each of the isolation transformers 124, as in the embodiments of Figure 11, the redundant regulator circuits 260 are coupled to each of the isolation transformers 124. Each redundant regulator circuit 260 has a separate output terminal 262.

On Page 18, amend Paragraph 0068 as follows:

[0068] Referring now to Figure 15, a block diagrammatic and schematic view of a triple redundant power distribution system 270 incorporating use of a redundant regulator circuit 152' in accordance with another embodiment of the present invention is shown. The distribution system 270 includes a pair of primary regulators 272, a pair of isolation transformers 273, and a redundant regulator circuit 152', which are similar to the regulators 122, transformers 124, and regulator circuit 152, respectively, of Figure 11. The triple redundant system 270 has three positive output terminals 274 292a, 292b, and 296 that provide three separate regulated power sources that are isolated from the primary regulators 272.

On Page 19, amend Paragraph 0070 as follows:

[0070] Voltage at two output terminals 292a, 292b are provided by a pair of secondary regulators 294 having input terminals 295 and output terminals 297. Voltage at a third or common output terminal 296 is provided by the redundant circuit 152'. The regulators 294 are coupled to respective cathode terminals 298 of diodes D1 and D4, to ground 258, and to the output terminals 292. Cathode terminals 298 are also coupled to respective positive terminals 300 of capacitors C1 and C5. Anode terminals 302 of the diodes D1 and D3 are coupled to secondary reception legs 304 of secondary coils 305 of the transformers 273. Positive terminals 308 of a pair of capacitors C4 and C8 are coupled to the output terminals 292.

On Page 19, amend Paragraph 0071 as follows:

[0071] The regulator circuit 152' includes a pair of regulators 158' and 160' having input terminals 309 and output terminals 310. The regulator 158' is coupled between capacitors C2 and C3 and the regulator 160' is coupled between capacitors C6 and C7. Positive terminals 312 of the capacitors C2 and C6 are coupled to cathode terminals 314 of diodes D2 and D3. Anode terminals 316 of the diodes D2 and D3 are coupled to legs 304. Positive terminals 318 of C3 and C7 are coupled to output terminals 296.

On Page 19, amend Paragraph 0072 as follows:

[0072] Regulators 158', 160', and 294 and negative terminals 320 of capacitors C1-C8 are coupled to ground terminal 258. The diodes D1-D4 direct current from the legs 304 to the regulators 158', 160', and 294 whereas the capacitors C1-C5 filter power received by the regulators 158', 160', and 294 and the output terminals ~~274~~.

On Page 20, amend Paragraph 0073 as follows:

[0073] Referring now to Figure 16, a block diagrammatic and schematic view of a triple redundant power distribution system 330 incorporating use of redundant regulator circuits 152" in accordance with another embodiment of the present invention is shown. The embodiment of Figure 16 is a modification of the embodiment of Figure 15 to provide negative output voltage at output terminals ~~274'~~ 292'a, 292'b, 296' and as such has similar reliability. Isolation transformers 332 each have a pair of secondary coils 334 as opposed to a single secondary coil, such as coils 305 in Figure 15. A pair of redundant regulator circuits 152" are also utilized instead of the single regulator circuit 152' and the pair of regulators 294 in Figure 15.

On Page 20, amend Paragraph 0074 as follows:

[0074] Each regulator circuit 152" includes a first regulator 158" and a second regulator 160" that are coupled between respective positive terminals 338 of capacitors C9-C16, similar to that of regulators 158' and 160' and capacitors C2, C3, C6, and C7 in Figure 15, via input terminals 309' and output terminals 310'. Diodes D5-D8 are coupled between the regulators 158" and 160" and respective secondary reception legs 334. Cathode terminals 339 of diodes D5-D8 are coupled to the regulators 158" and 160" and anode terminals 340 of diodes D5-D8 are coupled to legs 334.

On Page 20, amend Paragraph 0075 as follows:

[0075] Negative terminals 342 of capacitors C9, C10, C13, and C14 are coupled to output terminals 292'a, 292'b. Negative terminals 344 of capacitors C11, C12, C15, and C16 are coupled to common output terminal 296'. Positive terminals 338 of capacitors C10, C12, C14, and C16 are coupled to ground terminal 258.

On Page 21, amend Paragraph 0079 as follows:

[0079] For further increased reliability the systems 150, 150' 270, 330, and 350 of Figures 11 and 14-17 may be modified to include input distribution switches coupled between the sources 89 and the primary regulators ~~122 and 272~~, as is shown in Figures 6 and 9.

On Page 22, amend Paragraph 0081 as follows:

[0081] In step 400, the primary regulators ~~122~~ coarsely regulate and convert multiple power inputs received from the power sources 89.

On Page 22, amend Paragraph 0082 as follows:

[0082] In step 402, the isolation transformers 124 bi-directionally isolate coarsely regulated power out of the primary regulators 122 from the redundant regulator circuit 152 and generate isolated power for the regulator circuit 152.

On Page 29, amend the Abstract as follows:

ABSTRACT

[0088] A redundant power distribution system (74) that has multiple distribution lines (168) and (174) includes multiple regulators (122). Multiple isolation transformers (124) are coupled to the regulators (122) and have isolation boundaries (261). ~~An R(M/N)~~ redundant regulator device circuit (152) is coupled to the isolation transformers (124) to regulate the multiple distribution lines where M (integer) out of N (integer) distribution lines are required so that the system continues to operate properly. The regulators (122) and the isolation transformers (124) have a non-feedback looped configuration (259) across the isolation boundaries (261).